Li-ion Battery Foil Cutting Using Pulsed Green Lasers

Li-ion batteries have become a critical enabling technology in multiple product and market areas, including mobile devices, consumer electronics, telecommunications, clean energy storage, and hybrid and electric vehicles. The market for Li-ion batteries is forecast to reach $75 billion by 2020.

Li-ion battery manufacturing is a roll-to-roll process and can be divided into two main process chains: first, roll-to-cell production, and second, the cell-to-battery system assembly. Typical Li-ion battery cell structures consist of three layers of foils: the anode, the separator, and the cathode foil.

Lasers are well suited for addressing a number of steps in the manufacture of Li-ion batteries. In this Application Focus, we consider the foil-cutting process wherein anode and cathode foil strips are cut to a desired pattern as required by the cell design. Laser foil cutting provides many advantages over mechanical foil cutting techniques: it is a high-speed, high-precision, contact-free, cost-effective process with no tool wear, and it enables highly flexible pattern cutting and improved edge quality.

Depending on the cell design and whether or not the entire width of the foil roll is coated, during the cutting step the laser may need to cut through coated foils and/or bare metal foils. The thickness of electrode foils is typically ~100 µm. Anode foils are made of graphite-coated copper, and cathode foils are made of lithium-metal-oxide-coated aluminum.

The main quality challenges for laser cutting of Li-ion battery foils include minimization of heat-affected zones (HAZ) or "pull-back," which is a consequence of the conductive coatings being more easily ablated than the metal layers. Another potential issue is rough ridges left along the cut edges of the bare metallic sheets (generally known as burrs).

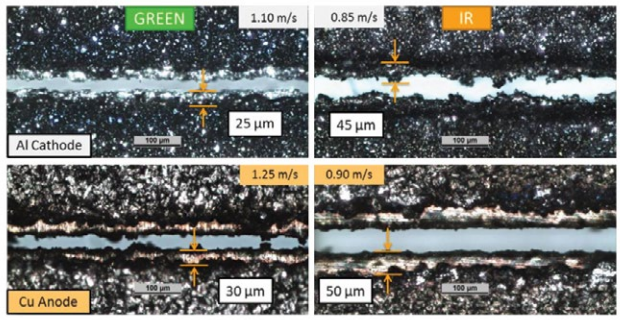

Figure 1: Comparison of entry-side cuts in coated aluminum (top) and copper (bottom) foils using a Quasar 75 W green hybrid fiber laser (left) and a 100 W IR pulsed fiber laser (right).

Typically, infrared (IR) Q-switched fiber lasers such as the Spectra-Physics® VGEN-QS-HE-100 are used for Li-ion battery foil cutting. The cut quality that pulsed IR fiber lasers can provide has been satisfactory for current applications in terms of HAZ and low burr.

In order to obtain even higher quality, pulsed green lasers such as the Spectra-Physics Quasar® 532-75 hybrid fiber laser can be used for battery foil cutting. In tests conducted by Spectra-Physics applications engineers, a Quasar 532-75 laser was used to demonstrate improved cut quality (smaller HAZ/burr) without sacrificing throughput. A comparison of results between IR and green laser cutting for coated foils is shown in Figure 1 and, for bare foils is shown in Figure 2. A summary of the results is shown in Table 1.

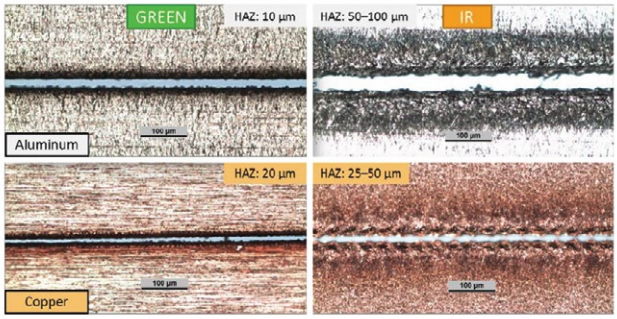

Figure 2: Comparison of entry-side cuts in aluminum (top) and copper (bottom) bare metal foils using a Quasar 75 W green hybrid fiber laser (left) and a 100 W IR pulsed fiber laser (right).

Laser-cutting of Li-ion battery foil materials is enabling improvement in quality and yield, and hence, reduced manufacturing cost. The foil-cutting process has been demonstrated with the Quasar high-power green hybrid fiber laser, yielding a significant improvement in cut quality compared with pulsed IR lasers without sacrificing throughput. Quasar laser's TimeShift™ programmable pulse technology is utilized for the best results.

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Foil Material/ Laser Wavelength	Cutting Speed (m/s)	Entrance Pull-back or HAZ/Debris (µm)	Average Burr Height (µm)
Coated Aluminum			
Green	1.25	20–25	2
IR	0.85	30–45	5
Coated Copper			
Green	1.10	25–30	2
IR	0.90	30–50	5
Aluminum			
Green	3.3	10	5
IR	3.50	50–100	3
Copper			
Green	3.75	20	2
IR	3.50	25–50	3

Table 1: Comparison of cutting results for electrode foil materials using a IR pulsed fiber laser versus a Quasar green hybrid fiber laser. Using 25% less power (75 W green vs. 100 W IR), similar cutting speeds with improvement in pull-back and HAZ/debris are observed.

PRODUCTS: *QUASAR 532-75, QUASAR 532-95*

The breakthrough performance of the Quasar series leads the industry with unprecedented high average power and energy at high repetition rates for fast micromachining. Quasar features novel TimeShift™ technology for programmable pulse profiles for the ultimate in process speed, flexibility, and control. Quasar 532-75 produces >75 W of green output power at 200 kHz and 300 kHz, and >375 µJ pulse energy. Quasar 532-95 produces >95 W of green output power and operates over a wide repetition rate range from single-shot to 3.5 MHz, with pulse widths from <2 ns to >100 ns. The Quasar family of lasers has excellent beam characteristics and very low noise. All of these characteristics contribute to the exceptional quality results demonstrated using Quasar.

	Quasar 532-75	Quasar 532-95
Wavelength	532 nm	
Power	>75 W @ 200 kHz	>95 W @ 200 kHz
Pulse Energy	>375 µJ	>475 µJ
Repetition Rate	0 to >1.7 MHz	0 to >3.5 MHz
Pulse Width	Programmable with TimeShift™	

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www.spectra-physics.com

3635 Peterson Way, Santa Clara, CA 95054, USA
PHONE: 1-800-775-5273 1-408-980-4300 FAX: 1-408-980-6921 EMAIL: sales@spectra-physics.com

Belgium	+32-(0)0800-11 257	belgium@newport.com	Korea	+82-31-8069-2401	korea@spectra-physics.com
China	+86-10-6267-0065	info@spectra-physics.com.cn	Netherlands	+31-(0)30 6592111	netherlands@newport.com
France	+33-(0)1-60-91-68-68	france@newport.com	Singapore	+65-6664-0040	sales.sg@newport.com
Germany / Austria / Switzerland	+49-(0)6151-708-0	germany@newport.com	Taiwan	+886 -(0)2-2508-4977	sales@newport.com.tw
Japan	+81-3-3794-5511	spectra-physics@splasers.co.jp	United Kingdom	+44-1235-432-710	uk@newport.com

SP-AP-20170504-35